IUCN SSC FRESHWATER PLANT SPECIALIST GROUP

Development of a conservation plan for Malabar river-lily (*Crinum malabaricum*)

April 2023

by
R.V. Lansdown, Ardeola Environmental Services, 45 The Bridle, Stroud, Glos., UK, GL5 4SQ,
Phone: 01453 763348

Cover images:

Above: Flower of Malabar River-lily (*Crinum malabaricum*) at the type locality near Periya Village, September 2017

Below: Students of the Government College Kasaragod in the river at Periya, with Prof. Biju Punnakot on the right, October 2022

Development of a conservation plan for Malabar river-lily (*Crinum malabaricum*)

April 2023

Contents

EXECUTIVE SUMMARY

The Malabar river-lily (*Crinum malabaricum*) is endemic to five sites on rivers in northern Kerala, south-western India and was described new to science in 2012. In 2016 it was assessed as Critically Endangered using the IUCN criteria; however research has shown that whilst still vulnerable, populations are fairly secure. The Red List Assessment for *C. malabaricum* needs to be revised, probably to Vulnerable D2, based on the small number of populations. Research projects were carried out in 2017 and 2022 in collaboration with students and staff of the Government College Kasaragod, funded by grants from the Mohamed Bin Zayed Species Conservation Fund, to assess the conservation condition of *C. malabaricum* and to devise a monitoring protocol. This report presents the results of the second project.

Four of the sites supporting *Crinum malabaricum* (at Aravanchal, Cheemeni, Embate and Periya) were visited on the 25th-27th September 2017 and four (at Aravanchal, Cheemeni, Eramam and Periya) on the 3rd-5th October 2022. *C. malabaricum* occurs on seasonal rivers flowing over level laterite at 80-100 m above sea level, in an area 20 x 5 km in Kannur and Kasaragod Districts, running parallel to the coast of northern Kerala. Populations appear to be limited upstream by reaches involving faster flow among bedrock outcrops and downstream by deeper water over silt.

Population estimates based on detailed recording at Periya suggest that the global population is in the region of 25,500 individuals distributed as follows: Aravanchal 500, Cheemeni 5,000, Embate 12,000 and Periya 8,000 individuals. All known populations have been abundantly fertile in both 2017 and 2022, flowering and setting seed abundantly from early September to late October. Potential seed-set in the population at Periya was estimated to be 2,250-33,750 in 2017 and 11,505-172,575 in 2022. Although *C. malabaricum* is capable of growing in full sunlight, this is rare, and most populations occur in the shade either of natural riparian woodland and scrub or fruit crop plantations. *C. malabaricum* typically forms dense stands covering the entire channel with leaves forming a dense mat as water levels drop. Due to its size and growth form, it grows with few other plant species, although where instream habitats or human activities reduce the cover of *C. malabaricum*, a range of other species occur such as *Eriocaulon heterolepis*, *E. dalzellii*, *Lagenandra toxicaria* and *Cryptocoryne spiralis*. Where the canopy is more open, other species may occur, such as *Blyxa aubertii* var. *echinosperma*, *Limnophila aquatica* and *L. repens*, with grasses such as *Isachne globosa*, *Oryza rufipogon* and *Sacciolepis interrupta* on the margins.

All the rivers which support populations of *C. malabaricum* have been extensively modified by man, mostly with a 2-3 m high wall of laterite blocks along one or both margins, other significant modifications are mainly associated with road crossings. Where there are significant interventions, such as major crossings or sites where people regularly use the channel, this creates gaps in the stands of *C. malabaricum*. *C. malabaricum* is a major ecosystem architect, providing shelter for fish and invertebrate communities, dramatically modifying the hydrology of the rivers and almost certainly playing an important role in nutrient cycling.

Overall, known populations of *C. malabaricum* may be considered stable and relatively secure, although there is potential for local actions to affect all populations. There is a suggestion that populations are in unfavourable condition at Cheemeni due to the rubber plantation, threatened at Aravanchal by housing and possibly declining at Embate due to development. There is a need for monitoring at all these sites to establish population trends. The apparent absence of a mechanism for formal protection of sites supporting *C. malabaricum* highlights the need for surveys of potentially suitable habitat within the known range of the species, as well as for monitoring of all know populations to identify population trends. More importantly, there is a need for a major initiative to stimulate and support conservation of wetland plants throughout the Western Ghats, to ensure conservation of *C. malabaricum* species and other taxa endemic to the region.

1 INTRODUCTION

The Malabar river-lily (*Crinum malabaricum*) was described new to science in 2012 (Lekhak and Yadav 2012) from a seasonal river in the vicinity of Periya Village, Kasaragod District in northern Kerala, south-western India. In 2016 on the basis of available information, *C. malabaricum* was classed as Critically Endangered under the IUCN Criteria (version 3.1) (Lansdown 2016). A project was developed to describe and document the population of *C. malabaricum*, the habitat on which it depends and any plausible threats to the known populations, to serve as a basis for monitoring and for any measures to protect the population. This project was awarded funding from the Mohammed bin Zayed Species Conservation Fund (Grant No. 172515103) and implemented in September 2017 (Lansdown and Molur 2017). During development of the project, contact was made with Prof. Biju Punnakot, Assistant Professor of Botany at the Government College, Kasaragod who has been surveying plants in the laterite plateaux in northern Kerala. In connection with these surveys he discovered an additional three populations of *C. malabaricum* in different rivers, another one in Kasaragod District and two in Kannur District before 2017.

Fieldwork for the project involved some documentation of all populations, but an opportunity was also taken to initiate development of a monitoring protocol for *C. malabaricum*, in combination with providing some training for students from the Government College Kasaragod. The results of the fieldwork were documented in a report (Lansdown and Molur 2017) which reached the following conclusions:

- Population estimates based on detailed recording of the population at Periya suggest that the global population was in the region of 25,500 individuals as follows: Aravanchal 500, Cheemeni 5,000, Embate 12,000 and Periya 8,000 individuals.
- *C. malabaricum* occurs within 20 km of the coast in four seasonal rivers at around 100 m a.s.l. in northern Kerala: Periya and Cheemeni in Kasaragod District and Embate and Aravanchal in Kannur District. The river reaches where *C. malabaricum* occurs are fairly level or gently sloping 2-5 m wide and <1 m deep, with a gravel bed and fairly fast flow. They all arise on the laterite and *C. malabaricum* only occurs where the rivers flow over the laterite.
- *C. malabaricum* typically forms dense stands covering the entire channel with leaves which form a dense mat as water levels drop.
- All four rivers have been extensively modified by man, mostly with a 2-3 m high wall of laterite blocks along one or both margins, other significant modifications are mainly associated with road crossings.
- Where there are significant interventions, such as major crossings or sites where people regularly use the channel, this creates gaps in the stands of *C. malabaricum*.
- *C. malabaricum* thrives in relatively fast-flowing water but appears unable to survive in standing water, it flowers and appears to set seed abundantly from early September to late October.
- *C. malabaricum* populations occur in reaches of rivers which flow through a range of habitats from relatively open gardens, through areca (betel) nut, coconut and rubber plantations to dense scrub and woodland.
- *C. malabaricum* typically occurs with species such as *Eriocaulon heterolepis*, *E. dalzellii*, *Lagenandra toxicaria* and *Cryptocoryne spiralis*, and where the canopy is more open, other species may occur, such as *Blyxa aubertii* var. *echinosperma*, *Limnophila aquatica* and *L. repens*, with grasses such as *Isachne globosa*, *Oryza rufipogon* and *Sacciolepis interrupta* on the margins.
- *C. malabaricum* is a major ecosystem architect, providing shelter for fish and invertebrate communities, dramatically modifying the hydrology of the rivers and almost certainly playing an important role in nutrient cycling.
- There are no obvious threats to the populations of *C. malabaricum* at Cheemeni, Embate and Periya, although there are anecdotal accounts of a decline at Embate. The monitoring baseline established at Periya should, if extended to cover the other populations, enable measurement of population trends and a response should a decline become apparent. The population at Aravanchal is threatened by destruction of adjacent laterite grassland for housing.
- The Red List Assessment for *C. malabaricum* needs to be revised, probably to Vulnerable D2, based on the small number of populations.
- There is a need for a major initiative to stimulate and support conservation of wetland plants throughout the Western Ghats, to ensure conservation of the species and other taxa endemic to the region.

A small number of other conclusions reached have subsequently been shown to be either premature or erroneous and are not repeated here.

Following on from this project, it was felt that a second project should be developed with the aims to:

a) Ground-truth the Periya data-set and compare the results with a second set of data to be collected in 2020,
b) Collect baseline data from the other sites supporting *C. malabaricum*.
c) Establish a monitoring protocol for all populations of *C. malabaricum*.

d) Raise awareness of the species and its role in the ecosystem with local people.
e) Train local students by involving them in collection of the monitoring baseline.
f) Transcribe field data and produce a summary report on all known populations
g) Make a report available to local government via the college to work toward protection of the *C. malabaricum* populations

A grant for this second project was awarded (No. 192522500) by the Mohamed Bin Zayed Species Conservation Fund. The covid pandemic made project work impossible or unwise during 2020 and 2021 and so the fieldwork was carried out in September 2022. Between 2017 and 2022 a fifth population of *C. malabaricum* had been found by Bjiu Punnakot at Eramam, also in Kannur District in northern Kerala. This document describes the current state of knowledge of *C. malabaricum*, considers potential for future conservation work and describes a monitoring protocol for this species. Information is presented in 4 chapters following this introduction:

- A summary description of all sites known to support *C. malabaricum*.
- A review of the conservation status of all known populations and description of the basis for development of a monitoring protocol.
- A compilation of information on the ecology of *C. malabaricum*.
- A summary of the conclusions reached through the work described here.

A proposed monitoring protocol is presented as Appendix A as a survey method. Throughout the text, descriptions and coordinates have been linked to nearby towns, rather than being precisely linked to the plan populations, to reduce the risk of the details in this report leading to damage to populations through collection. Precise details are available from the authors.

Acknowledgements

I am profoundly grateful to Sanjay Molur of Zoos Outreach Organisation for his help with project development, logistics, fieldwork management and data compilation. Biju Punnakot was also fundamental to the project, from showing us the sites, translation, identification of aquatic and other plants to providing extensive background data and particularly for making our baseline data collection possible. I would like to thank Shijith Puthan Purayil for bringing the students and helping both us and them with fieldwork, Usha Ravindra for help with baseline data collection with the students and other fieldwork, to Ranjith and Jinesh Kumar for their help with access to sites and to Christel Kasselmann and Karen Randall for additional background information. This project was made possible by a grant from the Mohammed bin Zayed Species Conservation Fund for which we are profoundly grateful.

The students who carried out fieldwork in 2017 were: Adithyamol, R., Akhila, M., Aryasree, M., Aswathi, K., Aswini Asokan, Athira V.J., Deepa, Harithanjali, B., Jasna Janardhanan, Meghana, P.S., Nishmitha Kumari S. Rai, Sajana, S., Shilpa, M., Shwetha, C.H., Sreelekha, A., Sreesanthi, C., Sreeshilpa, P. and Vaishna Thamban. Those in 2022 were: Bhavya K, Anjali C H, Arya Nanda E K, Harshitha C H, Nimmi Narayanan, Zainabath Raihana M A, Anagha Rajan, Arathi M, Bhagyalakshmi P, Keerthi P, Vidheya P, Anju J, Chanchal A V, Manju J, Anjali Rajan. I am very grateful to them for volunteering, as well as for their enthusiasm and interest.

2 SITE DESCRIPTIONS

2.1 Introduction

Crinum malabaricum is known to occur in five rivers in the northern part of Kerala State in south-west India. Four of these sites (Aravanchal, Cheemeni, Embate and Periya) were visited on the 25th-27th September 2017 and four (Aravanchal, Cheemeni, Eramam and Periya) on the 3rd-5th October 2022. Initial data collection involved a brief walk-over survey of readily accessible parts of each population, taking notes on the size of the population, as well as talking to local residents about the context and any potential threats. Subsequently, a day was spent working with students from the Government College Kasaragod in both 2017 and 2022 to collect a baseline for monitoring surveys (see chapter 3). This chapter provides a detailed description of each of the sites visited and details of the populations recorded.

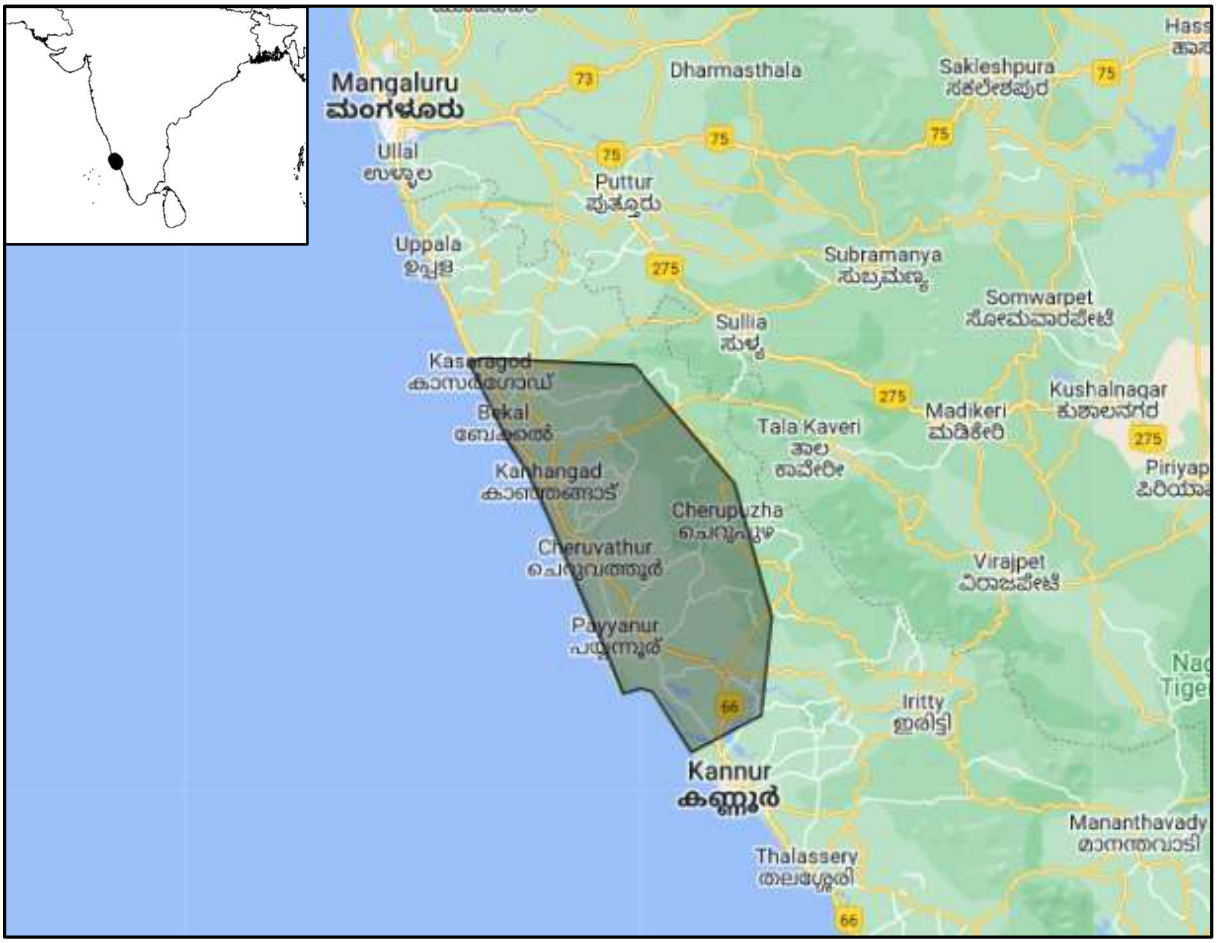

Figure 2.1 Map of the coast of north-west Kerala, showing the locations of the known populations of *C. malabaricum* (Google Maps). Inset: Location of in relation to India as a whole.

2.2 Aravanchal, Kannur District

Location: 12°12'34.3" N, 075°17'02.3" E, 100 m a.s.l.

Population

The river arises in a sacred grove and the population of *C. malabaricum* occurs almost from the source for at least 800 m downstream. Toward the upstream end of this section the population was sparse as the river flows over bedrock exposures, but downstream of these immediately becomes dense, reaching 100 % cover. However, *C. malabaricum* is apparently absent where a road crosses the river approximately 1 km downstream of the "sacred grove". It is not possible to provide a meaningful estimate of the total population, but the parts surveyed involved at least 1000 individuals.

Adjacent habitat

The river arises within a stand of native forest which is protected as a sacred grove, downstream of this the river passes through coconut and areca nut plantations. Beyond these, the land to the south is mainly characterised by extensive species-rich laterite grassland with mature, native riparian woodland along the river.

Figure 2.2 The river alongside the sacred grove at Aravanchal, showing scattered *C. malabaricum* among bedrock exposures

Figure 2.3 The river immediately downstream of the spring at the sacred grove at Aravanchal

Associated species

The only species occurring in the water with *C. malabaricum* at this site were *Cryptocoryne spiralis*, *Eriocaulon dalzellii*, *E. heterolepis* and *E. setaceum*.

Threats

Parts of the open laterite grassland alongside the sacred grove and extending some way downstream have been assigned to housing development. This may represent a significant risk to this population, however there was no evident change to land use or construction activity between visits made in 2017 and 2022. Threats from housing would include risk of direct damage, run-off causing sedimentation and untreated waste entering the water course.

2.3 Cheemeni, Kasaragod District

Location: 12° 14' 17.61" N, 75° 13' 15.21" E, 93 m a.s.l.

Population

The population of *C. malabaricum* at Cheemeni was between the road bridge and the first house downstream of this. A visit was made downstream of this house and no *C. malabaricum* was seen, although it is possible that there were further stands downstream of this or even upstream of the road. Throughout the section surveyed, *C. malabaricum* occurred at very high density, typically ≥80 % cover except for a 20 m section downstream of the road bridge and a gap where people cross the river. The length of river supporting dense populations was approximately 500 m and it is not unreasonable to estimate a population density of 100 plants per 10 m section (through comparison with stands documented at Periya). Therefore, the population recorded at Cheemeni may be estimated at 5,000 individuals.

Figure 2.4 *C. malabaricum* in the river flowing through the rubber plantation at Cheemeni. This clearly shows the start of degradation of plants as water levels had dropped prior to the survey.

Adjacent habitat

The section of river surveyed at Cheemeni was bounded on both sides by a rubber plantation with dense ground cover. It is of note that this is the only river section supporting *C. malabaricum* during this project which had not been modified in the past by installation of a wall along one bank. Beyond the rubber plantation land was given over to improved pasture, laterite grassland and disturbed ground supporting ruderals.

Figure 2.5 *C. malabaricum* in the river flowing through the rubber plantation at Cheemeni. Again showing the start of degradation of plants as water levels had dropped prior to the survey.

Associated species

No other species were recorded in the river along the section supporting *C. malabaricum*.

Threats

It is likely that management of the rubber plantation could result in siltation of the river, probably combined with nutrient enrichment due to fertiliser application and possibly leaching of pesticides. In 2017 the condition of the *C. malabaricum* population throughout the plantation appeared very good, however in 2022 it was noted that, in contrast to all other populations, most flowers were dying without developing seed (apart from a single ripe fruiting head). It is possible that the lack of a shrub layer in the rubber plantation, compared to forest and tree-crop plantations at other sites, makes plants more vulnerable to direct heat of the drying effect of wind. It will be very important to monitor population trends at this site to ensure that management of the rubber plantation is not having an adverse impact.

2.4 Embate, Kannur District

Location: 12° 04' 03.19" N, 75° 18' 17.3" E, 82 m a.s.l.

Population

The population at Embate was not surveyed in full but a length of approximately 200 m of the river was surveyed in 2017. One of the landowners told us that *C. malabaricum* does not occur within 1 km of the source, but is abundant for 2-3 km before the river widens, becoming deeper and slower-flowing, this estimate was not verified. Along the section surveyed, *C. malabaricum* achieved cover values similar to or possibly slightly lower than those at Periya. A conservative population estimate, assuming cover of 60 individuals per 10 m over a length of 2 km would suggest that this population could involve approximately 12,000 individuals. Even if this is an exaggeration, it is clear that the population at Embate is very large.

Adjacent habitat

The banks throughout much of the river section visited had been modified by installation of laterite blocks to form a wall 2-3 m high. Beyond this, the adjacent land was characterised by a sparse settlement with gardens and coconut plantations.

Figure 2.6 Flowering and fruiting *C. malabaricum* in the river at Embate, showing the laterite block wall

Associated species

The river at Embate contained very few species of plant in the section visited, *C. malabaricum* was the most abundant species, apparently to the exclusion of other plants. Where flow was broken or faster (such as along a section narrowed by hard banks on both sides), other species such as *Eriocaulon dalzellii*, *E. heterolepis* and *Limnophila repens* became dominant and *C. malabaricum* very sparse.

Threats

According to one of the adjacent landowners, there has been a decline in the population of *C. malabaricum* in the river following bank strengthening and possibly also related to clearing the river for gravel. This has been represented by more gaps appearing between plants.

2.5 Eramam, Kannur District

Location: 12° 08' 50.71" N, 75° 16' 37.37" E, m a.s.l.

Population

The population seen at Eramam was divided into two areas, an upstream area, where *C. malabaricum* occurred at high cover values in the shade of native riparian forest and scrub, separated from a second area by steeply sloping broken channel flowing between large laterite boulders. The second area then supported at least 500 m of *C. malabaricum* occurring at 80-100% cover under the shade of a fairly dense tree canopy.

Adjacent habitat

In the upstream area, *C. malabaricum* occurred in a section lined by native trees and scrub. Downstream of this, a small patch occurred in the open, among bare or sparely vegetated laterite grassland with a range of species in the water including *Eriocaulon dalzellii* and *E. heterolepis*. The downstream section occurred in a section of river flowing through plantations, dominated by areca nut but with a high diversity of mixed crop trees, as well as scattered species such as fishtail palm (*Caryota* sp.) alongside the channel.

Associated species

Under closed tree canopy, *C. malabaricum* occurred mainly as a monospecific stand, with other species only occurring where the canopy was more open. Immediately downstream of the main population in the upstream area,

there was a deep pool with a wide range of aquatic plant species, including *Blyxa aubertii*, *Eriocaulon dalzellii*, *E. heterolepis*, *E. setacea* and *Limnophila repens*, as well as a planted *Nymphaea* sp.

Figure 2.7 *C. malabaricum* in the downstream section at Eramam showing abundant flowers and fruit

Figure 2.8 *C. malabaricum* in the downstream section at Eramam showing immature plants with short, narrow leaves

Threats

The upstream area is much used by people and there is an area of laterite which has relatively recently been quarried. There are no obvious threats, although any clearance of tree cover could have an adverse effect on the population. The downstream area appears to be very stable and the population here secure.

2.6 Periya, Kasaragod District

Figure 2.9 Part of the C. malabaricum population at Periya, showing 100% cover of leaves with frequent flowers

Location: 12° 24' 05.90" N, 75° 05 50.08" E, 102 m a.s.l.

Population

This is the type locality and best known of the sites, it was also the focus of the monitoring baseline collected in September 2017 and 2022. *C. malabaricum* occurs over a length of at least 1 km upstream of the road bridge and 400 m downstream, possibly with a maximum length for the population of 1500 m. Counts taken from areas of dense growth ranged from 45 plants per 10 m, where the channel was narrowed by laterite exposures, to 130 plants per 10 m at a point where the channel was broad and of even depth, with an average of about 80 plants per 10 m. Taking into account gaps of 100 m downstream and 50 m upstream of the road bridge, c 150 m associated with the partial dam and footbridge, together with an estimated total of 100 m of gaps due to washing pools and laterite outcrops, the total population of *C. malabaricum* in this population can be estimated to be 8,000 plants. More detail on the composition of the population is provided in Chapter 3.

Adjacent habitat

The river arises on higher ground approximately 2 km east of the road bridge. Initially it flows through secondary vegetation and open laterite grassland before dropping down through gardens to a section with rice fields on either side, at which point *C. malabaricum* starts to occur as scattered plants. Downstream to the road bridge, the land alongside the river generally holds a combination of coconut and areca nut plantations and gardens which include coconuts but also have a range of fruit and ornamental trees. Throughout this section, *C. malabaricum* typically occurs at ≥80% cover apart from particular situations. Immediately upstream of the road bridge, there is a short area of secondary growth where *C. malabaricum* is sparse. For approximately 100 m downstream of the road bridge, the river flows through open grassland and secondary scrub where *C. malabaricum* is very sparse or absent, before entering a coconut plantation where it is again abundant to dominant. The downstream end of the population

was not mapped precisely, but there was no evidence of the population at a point approximately 1 km downstream of the road bridge.

Associated species

At this site, upstream of the road bridge for c 300 m and downstream of the road bridge, the channel also supports a wide range of aquatic species, including *Blyxa aubertii* var. *echinosperma*, *Eriocaulon heterolepis*, *E. dalzellii*, *E. setaceum* and *Limnophila aquatica*. In the area immediately upstream of the track bridge, where water is ponded by a weir, these species occurred in abundance in 2017 with a fine-leaved *Najas* sp. but by 2022 these had largely been replaced by a large, dense stand of *Sacciolepis interrupta*. Throughout this area, the margins also support *Isachne globosa*, *Sacciolepis interrupta* and *Oryza rufipogon*. Upstream of this area where the river flows through fairly dense shade, *C. malabaricum* is the only species occurring in the channel. Further upstream again, particularly where the channel includes laterite outcrops, there are extensive stands of *Eriocaulon dalzellii*, with grasses where soil collects. *Cryptocoryne spiralis* var. *caudigera* was recorded at a single site, where a track crosses the channel and a small stand of *Lagenandra toxicaria* occurred about 50 m downstream of this.

Figure 2.10 A group of students at Periya, documenting the *C. malabaricum* population

Threats

There are no obvious and immediate threats to the population of *C. malabaricum* or associated habitats at Periya. It is likely that the main action directly affecting *C. malabaricum*; clearing or suppression of patches where local people use the river, has been happening for a long time and does not appear to have any significant effect on the overall population. Similarly, collection of flowers for a festival shortly before the visit in 2022 does not appear to have reduced the vast number of seed produced. However it is clear that interventions such as the installation of concrete walls (as opposed to the laterite block walls traditionally used) and weirs have a dramatic adverse effect on populations and no further interventions of this nature should be permitted.

3 ECOLOGY

3.1 Habitat and distribution

All known populations of *C. malabaricum* are located on rivers within an area approximately 20 km long and 5 km wide, running parallel to the coast of Kerala at an altitude of 80-100 m above sea level, in a belt of relatively low-lying hills, characterised by extensive laterite exposures. The rivers are tributaries of more than one and probably a total of three large rivers. All of the rivers supporting *C malabaricum* arise from the laterite, and either initially descend rapidly before reaching a more or less level plateau or arise on plateaus. Laterite bedrock exposures dominate in the first stage of the rivers but typically occur only as discrete patches in the middle and lower stages. Where *C. malabaricum* occurs among these exposures, it grows in gravel deposits on the rock or between outcrops. All of the rivers are seasonal, beginning to flow in May or June when the monsoon rains begin and flowing until January or February, when they dry out completely. River sections supporting *C. malabaricum* are all 2-5 m wide, with fast-flowing water approximately 0.5 m deep at the time of survey (i.e. during flowering and fruiting of *C. malabaricum*). As discharge declines, flows are reduced and the water becomes shallower, eventually breaking up onto ponded, still sections. Downstream, as the water becomes deeper due to frequent inflowing streams, *C. malabaricum* declines and disappears. Subsequently, the rivers become broad and often slow-flowing before entering one of the larger rivers which take the water to the coast. The upstream and downstream limits of *C. malabaricum* populations appear to be dictated by broken flow and by water deeper than approximately 50 cm at the peak flowering period respectively.

Figure 3.1 A typical stand of *C. malabaricum* in the river at Periya, showing gaps in stands around bedrock exposures, which support *Eriocaulon heterolepis*, but 100 % cover further downstream

The bed material associated with each population was dominated by laterite gravel with material ranging from fine grit to small or even medium-sized stones, all of the rivers include local silt deposits where flow slows, but these deposits do not generally support *C. malabaricum*. All five populations are in river sections which flow mainly either through natural riparian woodland or tree crop plantations which are often mixed and include areca, cashew and coconuts, bananas, bread and jack fruit, rubber and teak. Whilst *C. malabaricum* appears able to tolerate complete sunshine (e.g. at Eramam and Aravanchal), the healthiest populations with the largest numbers of flowers and ripe fruit were under a closed canopy of tall trees.

In general, *C. malabaricum* occurs directly with few or no other species, at least in part because it tends to cover the entire channel and may preclude growth of other vegetation. Only where some factor such as silt banks, bedrock exposures, deeper water or human intervention breaks up populations of *C. malabaricum* do other species occur within

the river channel. *Cryptocoryne spiralis* var. *caudigera* and *Lagenandra toxicaria* occur among stands of *C. malabaricum* at Periya, with the former also at Aravanchal, while sections of rivers which do not support *C. malabaricum*, but in areas where it occurs, typically support a range of aquatic species such as *Blyxa aubertii* var. *echinosperma*, *Eriocaulon dalzellii, E. heterolepis*, *E. setaceum*, *Limnophila repens* and *Limnophila aquatica*, with *Isachne globosa*, *Sacciolepis interrupta* and *Oryza rufipogon* in the margins or occasionally forming stands in the channel.

All of the rivers supporting *C. malabaricum* have been modified by humans for some time; most are lined on at least one margin by a 2-3 m high wall of laterite boulders. These walls and their effects on the hydrology of the rivers do not appear to have affected *C. malabaricum*. However, it is notable that as soon as there is an intervention, such as direct use of the channel, modification of flow or disturbance of the banks, *C. malabaricum* becomes more sparse (gappy).

3.2 Population dynamics

All populations included flowering plants both in 2017 and 2022 (at the Periya population in 2017, approximately 1: 5 plants had inflorescences in sections surveyed) and a fairly high proportion of these produce fruit which develop and appear to ripen. All populations showed successive stages of flowering, from inflorescences in which the buds had yet to develop, through open flowers to fully mature fruit (although at Eramam, most flowers appeared to have aborted before fruit developed). From the different stages of development of the flowering parts seen during surveys, it would appear likely that the process from initiation of the inflorescence through to ripening of the fruit takes at least a few weeks and probably more than a month. Thus, it is reasonable to conclude that *C. malabaricum* flowers at least from mid- to late-August until the end of October. The survey in 2022 was approximately ten days later than that in 2017 and not only were there many more flowers, but much larger numbers of mature fruit (Table 3.1). Ripe seeds sink immediately and in 2022 many were apparent on the bed of the rivers, following fruit dehiscence (Figure 3.3).

C. malabaricum typically occurs at >80% cover in the channel, to the extent that it impedes flow, except for five situations:

- Among laterite outcrops which limit the channel such that flow is narrow and fast, it occurs only as scattered plants.
- Where local people enter the channel to wash clothes or cross the river, this creates gaps in the population, partly apparently as a consequence of the direct disturbance but also partly by cutting plants.
- At a point, c 200 m upstream of the road bridge at Periya, where the banks have been completely replaced by concrete and a partial dam installed beneath a foot-bridge, the water is deep and flow slow and *C. malabaricum* is absent. There is also point c 100 m downstream of the road bridge where flow is deep and slow and *C. malabaricum* largely absent. It is likely that the change in flow and consequent absence of *C. malabaricum* are due to artificial modification of the channel.
- Immediately upstream, downstream and beneath bridges, *C. malabaricum* is absent.

Table 3.1 Population and reproductive characters (NR indicates not recorded)

Section	No. Plants	No. unopened inflorescences	No. buds	No. flowers	No. unripe fruit	No. ripe fruit
2017						
Upstream 1a	512	NR	18	15	46	43
Upstream 1b	151	NR	15	15	11	24
Upstream 1c	935	NR	14	6	10	17
Total	**1598**		47	36	67	84
as 500 m 2017	2663		78	60	112	140
2022						
upstream 1	1329	25	212	348	204	208
upstream 2	2721	9	245	671	562	449
downstream	573	5	38	107	392	400
Total	**4623**	**39**	**495**	**1126**	**1158**	**1057**

Table 3.1 shows the results of counts of numbers of plants and reproductive characters in the two years. In 2017, details were recorded only on three 100 m sections of the river, upstream of the road bridge, in contrast in 2022 details were recorded on three separate 500 m sections (with data actually broken down into 100 m sections), one downstream and two upstream of the road bridge. Data from 2017 have been extrapolated to indicate what the values would represent if they had been recorded over a 500 m length, rather 300 m ("as 500 m in 2017").

Figure 3.2 A dehisced capsule and ripe capsules of *C. malabaricum* in the river at Periya

Figure 3.3 Mature seeds of *C. malabaricum* on the bed of the river at Periya

These data have then been extrapolated to give an indication of the total maximum and minimum potential seed-set per 100 m in each year, based on the number of seeds per capsule indicated by Lekhak and Yadhav (2012) (who give a range of 3-16). This suggests a potential seed-set of 150-800/100m in 2017 and 767-4092/100 m in 2022. This analysis clearly shows the much higher rate of flower and seed production in 2022 and it is also of note that large numbers of seeds were seen resting on the substrate after fruit dehiscence in 2022 but none noted in 2017. It is likely that this simply represents typical annual variation and data collected over a number of years will be needed before any meaningful attempt can be made to establish trends in reproductive potential. Whilst this assessment is fairly speculative (for example it is highly unlikely that all buds would develop to set seed, particularly as at least one caterpillar species appears preferentially to feed on the developing seeds), it is clear that this population has enormous reproductive potential, given that it stretches for approximately 1.5 km..

Table 3.2 Potential maximum and minimum seed-set per 100 m in 2017 and 2022

	No. buds	No. flowers	No. unripe fruit	No. ripe fruit	**Total**
2017					
min		47	36	67	**150**
max		251	192	357	**800**
Potential total seed-set		**705-10,575**	**540-8,100**	**1,005-15,075**	**2,250-33,750**
2022					
min	99	225	232	211	**767**
max	528	1201	1235	1127	**4092**
Potential total seed-set	**1,485-22,275**	**3375-50,625**	**3,480-52,200**	**3,165-47,475**	**11,505-172,575**

It might be expected that *C. malabaricum* is a long-lived perennial, due to the size of the bulb (Lansdown and Molur 2017), combined with the development of subsidiary bulbs (Lekhak and Yadhav 2012). However, the massive potential and high observed seed-set, combined with movement of stands between 2017 and 2022 (based on mapping) as well as the observation of young plants with short, narrow leaves arising from small bulbs at Eramam (Fig. 2.8) suggests that populations may actually be highly dynamic and plants may actually be quite short-lived, forming dynamic populations.

Figure 3.4 A caterpillar feeding on an inflorescence of *C. malabaricum* at Periya in 2022

The occurrence of a large plant such as *C. malabaricum* in small water courses where its own growth significantly modifies the hydrology progressively as water levels decline and the rivers dry out, is unusual. it is echoed only by species such as *C. thaianum* in Thailand (Pradissan and Pipatcharoenchai 2008) together with the larger *Ranunculus* Sect. Batrachium taxa and some *Potamogeton* species in Europe (Lansdown 2007) and North America, although these typically occur in larger, perennial water courses. It is possible that this high density is important for the survival of *C. malabaricum* populations and almost certain that *C. malabaricum* can be considered an ecosystem architect and keystone species where it occurs. Pradissan and Pipatcharoenchai (2008) note the importance of *C. thaianum* for fish and anecdotal observations suggest that there is also a strong association between *C. malabaricum* and fish communities.

Figure 3.5 Students from the Government College Kasaragod counting buds in an inflorescence at Periya in 2022

The sheer size of the plants and the density at which they occur mean that as the water levels drop and the rivers ultimately dry out, the plants initially force flow into narrower pathways within the channel and then represent a massive quantity of degrading vegetation which must have implications for the nutrient status of the bed material. The process of degradation of the plants is aided by grazing caterpillars, tentatively identified as the larvae of the Indian lily-moth (*Polytela gloriosae*) which can occur in very large numbers and are reported to completely graze out large populations before the rivers dry out completely, although they were mainly seen eating inflorescences in 2022.

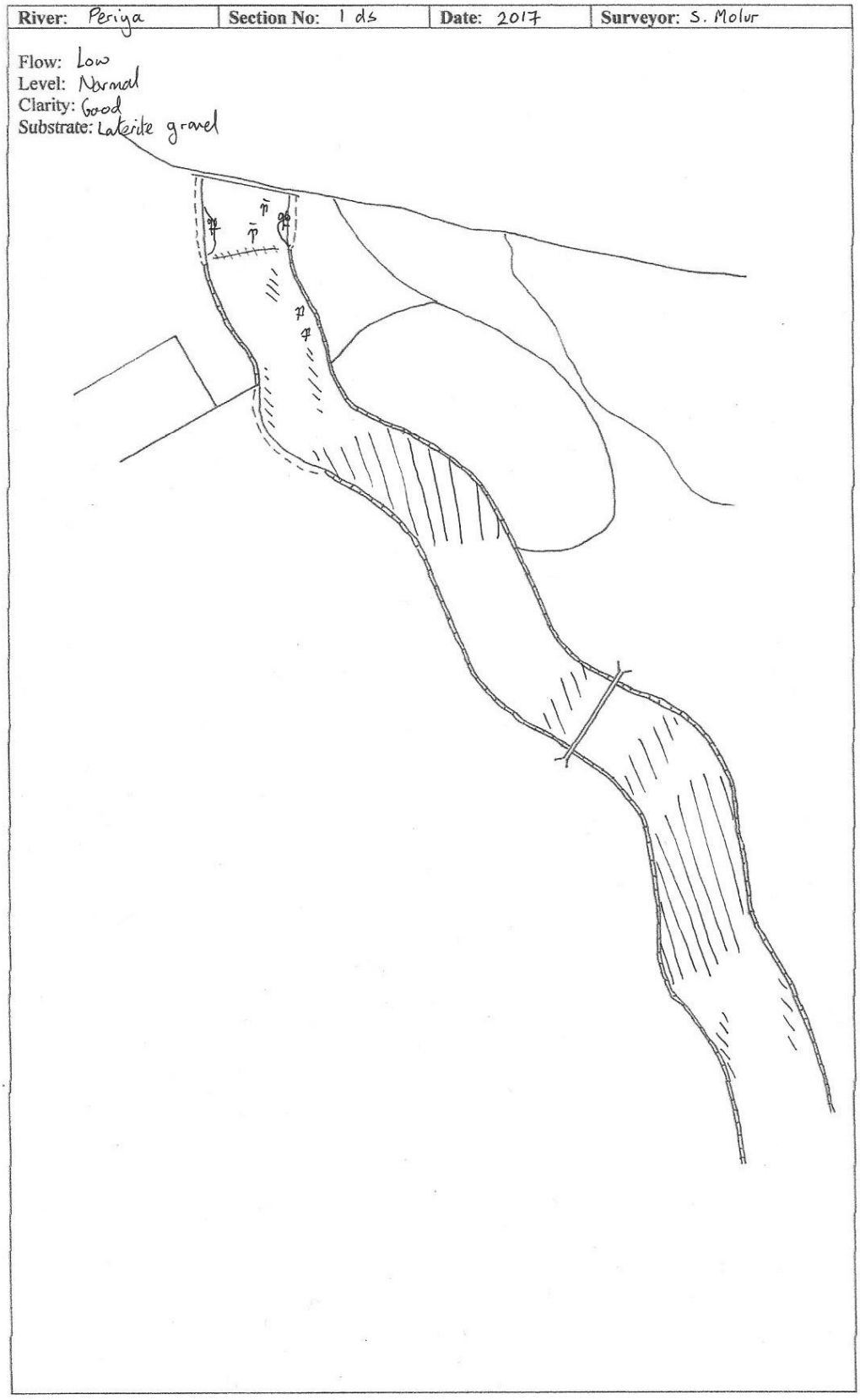

Figure 3.6 Sketch map of the distribution of *C. malabaricum* downstream of the road at Periya in 2017

Figure 3.7 Sketch map of the distribution of *C. malabaricum* downstream of the road at Periya in 2022

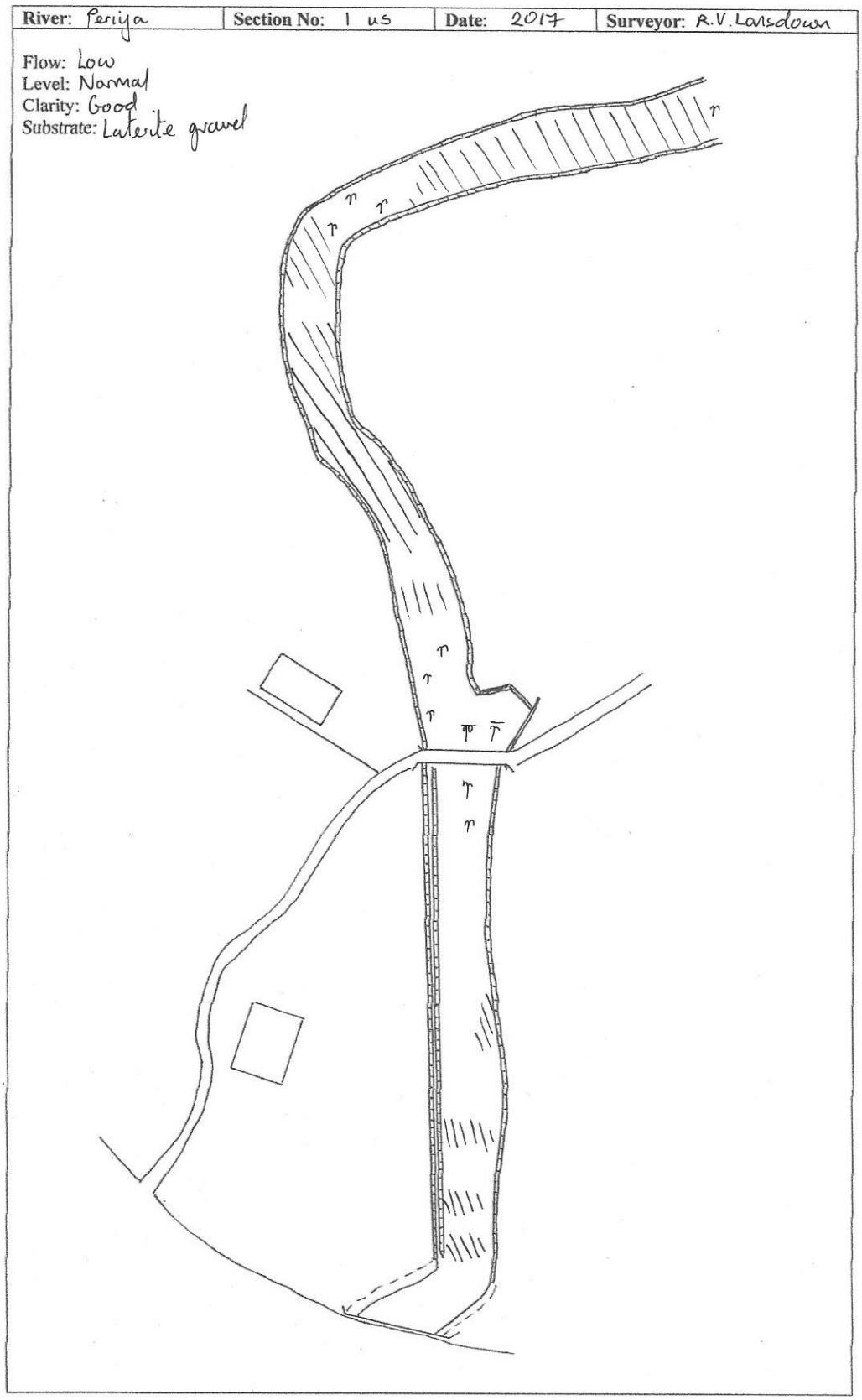

Figure 3.8 Sketch map of the distribution of *C. malabaricum* on section 1 upstream of the road at Periya in 2017

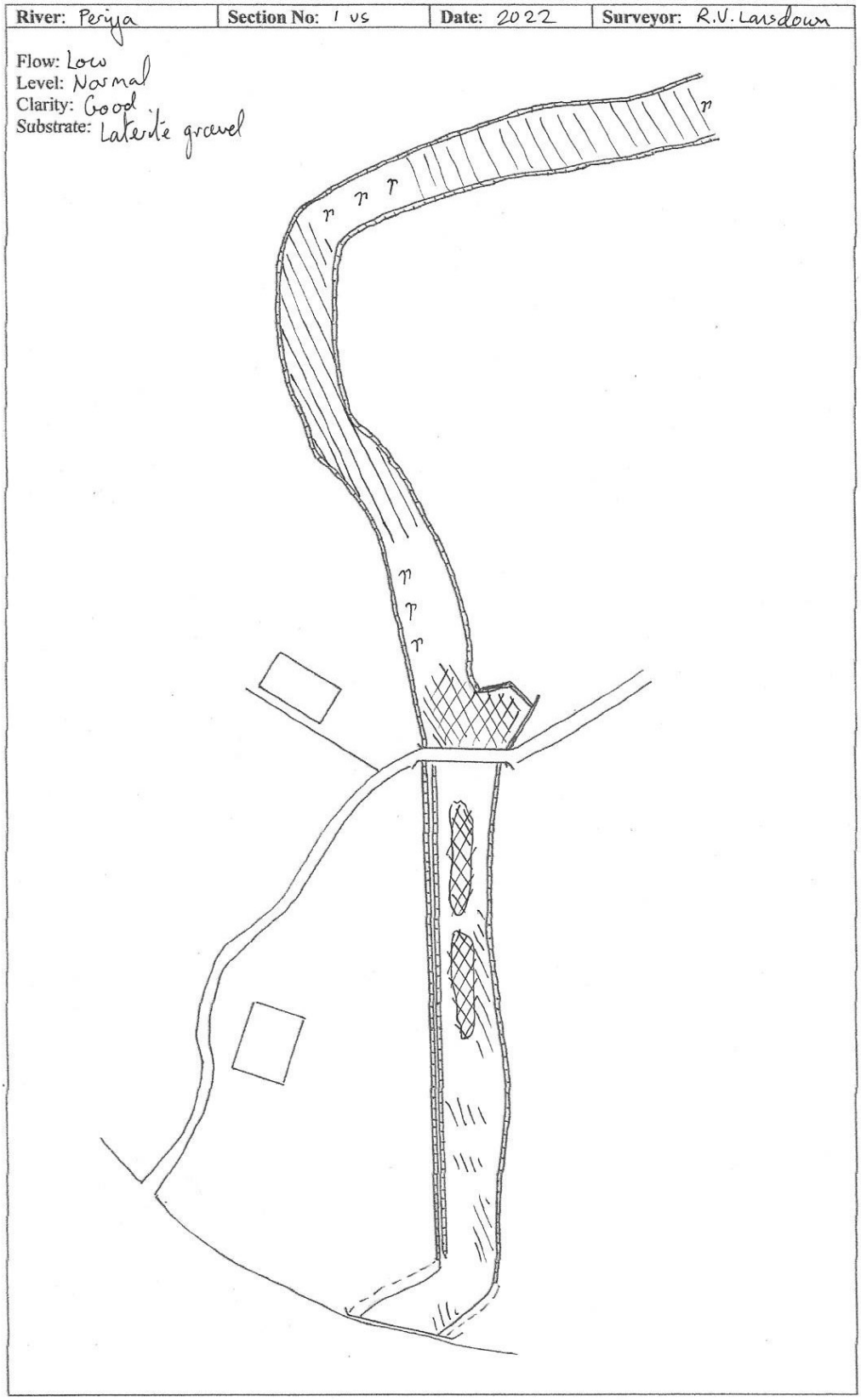

Figure 3.9 Sketch map of the distribution of *C. malabaricum* on section 1 upstream of the road at Periya in 2022

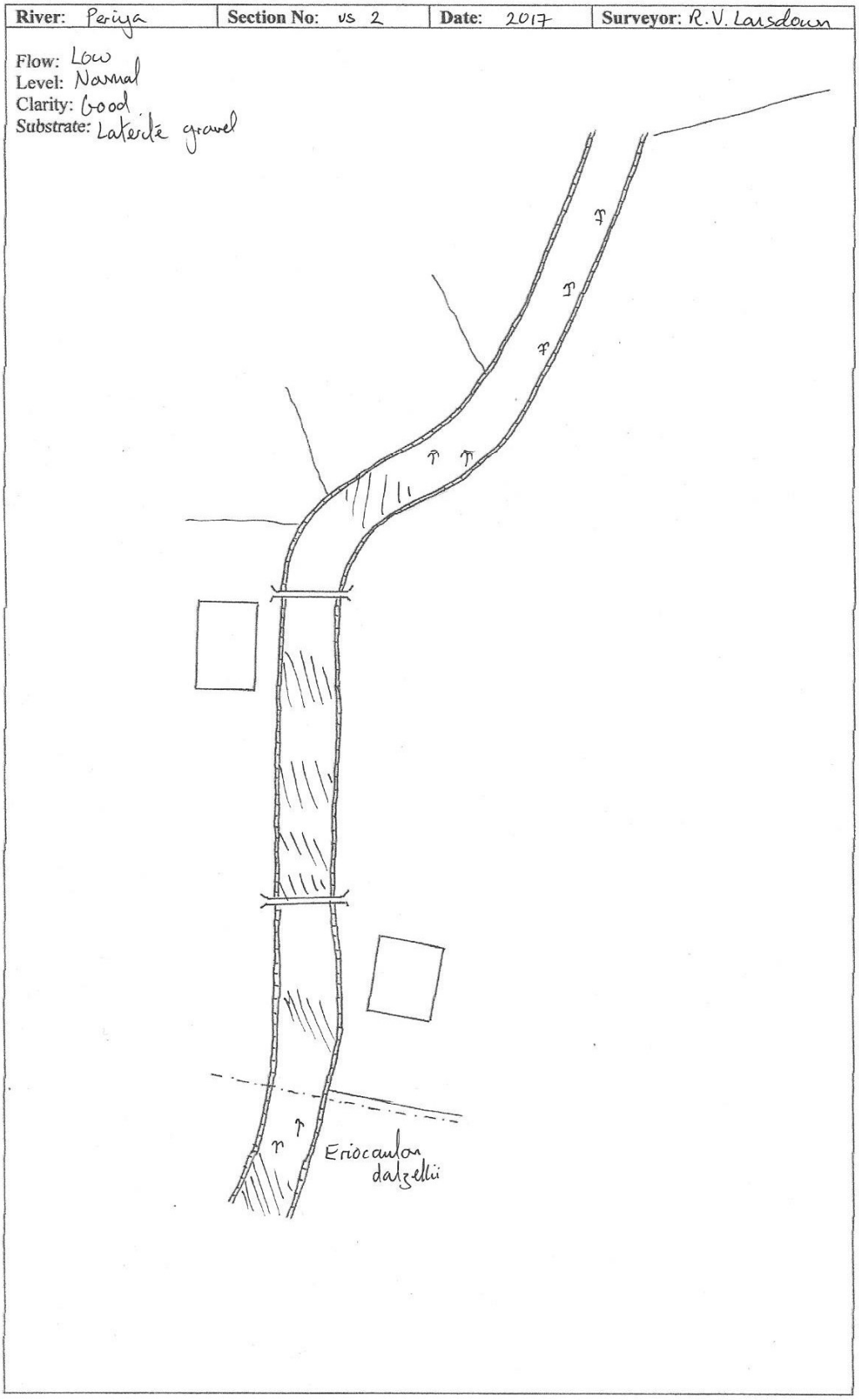

Figure 3.10 Sketch map of the distribution of *C. malabaricum* on section 2 upstream of the road at Periya in 2017

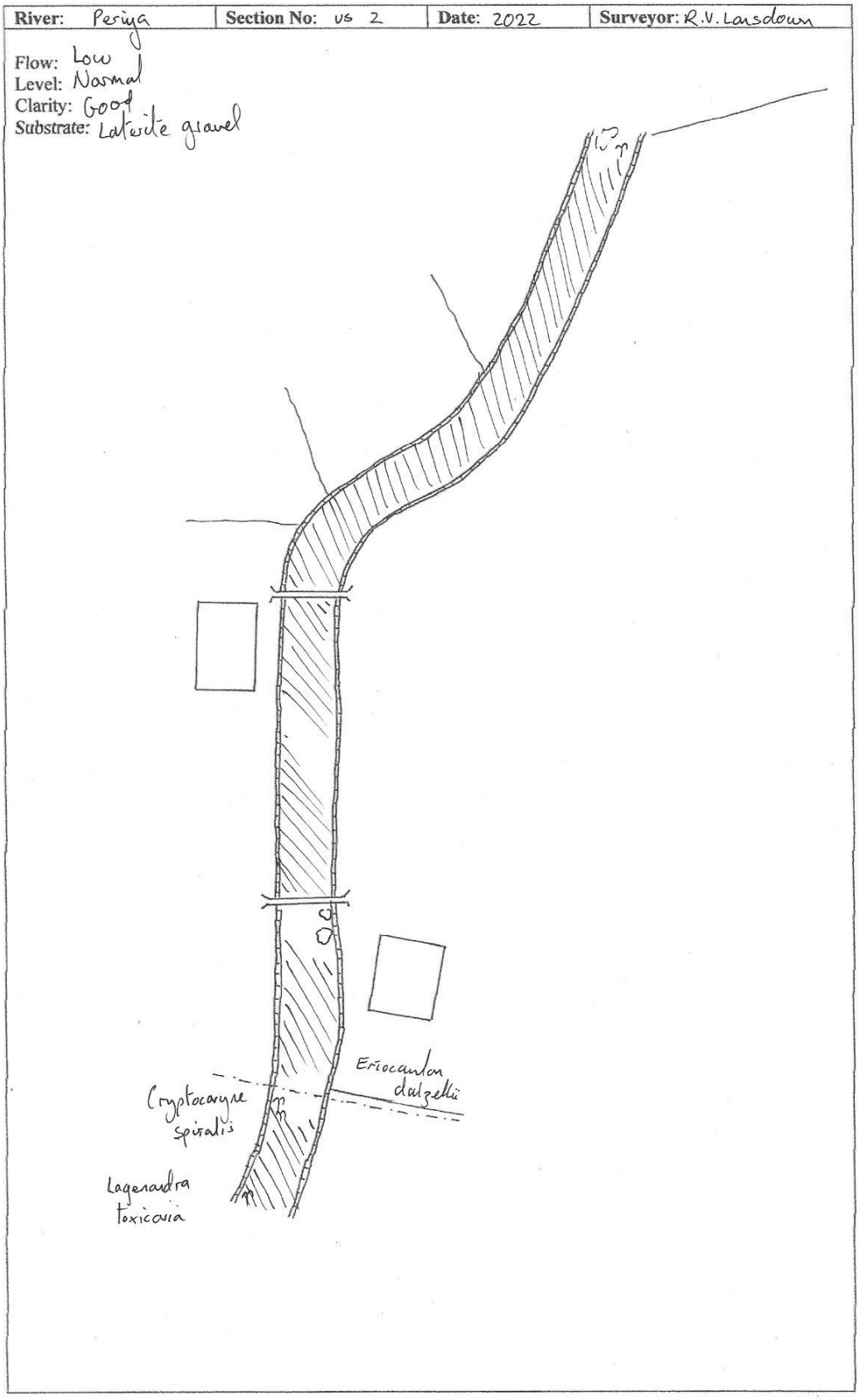

Figure 3.11 Sketch map of the distribution of *C. malabaricum* on section 2 upstream of the road at Periya in 2022

Plants grown in permanent standing water in the Malabar Botanical Garden in Kozhikode (Calicut) have survived for a few years but in declining condition (R. Prakashkumar pers. comm.). Similarly plants transplanted to a river on granite to the north of Periya have also died (B. Punnakot pers. comm.). Plants grown permanently submerged in flowing water in large tanks have survived for nearly ten years, going dormant for several months per year and only once producing a single flower, but re not as vigorous as wild plants (C. Kasselmann pers. comm.).

3.3 Dispersal

It appears likely that within a river that is on suitable habitat, *C. malabaricum* is capable of colonising areas where flow is relatively smooth and the depth does not exceed 50 cm. It is not obvious how seed might travel upstream or between catchments. The most likely dispersal vector would be large herbivores which might enter rivers to eat either the leaves or developing fruit. However large herbivores are no longer present in the area and there is no other obvious dispersal vector available.

4 POTENTIAL FOR CONSERVATION AND MONITORING

4.1 Conservation

The conservation condition of known populations of *C. malabaricum* can be summarised as follows:

1. Aravanchal - Adjacent laterite grassland has been allocated to housing and although the *C. malabaricum* population is protected by the status of the sacred grove, it is vulnerable to secondary effects of housing development such as pollution, mobilisation of sediment and increased domestic use of the river.
2. Cheemeni – There is no evidence of a decline in the population, but in 2022 most inflorescences appeared to be aborting before fruit began to develop. There is no immediately obvious cause for this sterility, but if it continues, it could compromise the resilience of the population. It is possible that the lack of a shrub layer in the rubber plantation, compared to forest and tree-crop plantations at other sites, makes plants more vulnerable to direct heat of the drying effect of wind.
3. Eramam – The upstream part of this population appears fairly stable, but may be vulnerable to short-term changes in use of the site by local people. The downstream part appears to be stable and relatively secure.
4. Embate – It has been reported that this population has already been affected by modification of adjacent habitats and that the decline is continuing. It was not possible to confirm this decline or document the condition of this population in 2022.
5. Periya – This population appears able to tolerate the effects of the use of the river by local people and appears to be in a similar condition to when it was surveyed in 2017. It can therefore be considered to be stable and relatively secure.

Figure 4.1 The river immediately upstream of the track bridge and weir at Periya, showing the dense growth of *Sacciolepis interrupta* in 2022

All flowing waters in India are owned by the state and this is taken to include the bed of the watercourse. In contrast, the banks are owned privately and can apparently be modified without any form of planning control. Clearly, although the actions which appear to have had the greatest effect on existing populations have involved large-scale modification of the rivers such as works associated with the track bridge at Periya which completely altered the vegetation (Figure 4.1), there is also potential for small-scale local works to damage *C. malabaricum* populations. The most effective way to avoid such damage is to ensure that local residents are aware of the species and its conservation importance, as well as understanding that their actions could have a dramatic adverse effect on it. The first steps toward informing

local people about the species have been achieved, initially through visits by foreign botanists such as Karen Randall and Christel Kasselmann and more recently through the involvement of the students from Government College, Kasaragod in the monitoring. The lecturers and students from the college have the best potential to communicate the conservation message to local people and this should become part of the annual monitoring work.

In the absence of a mechanism for formal protection of sites supporting *C. malabaricum*, it is difficult to see what conservation action could be taken to enhance the conservation condition of *C. malabaricum* populations, apart from discussion with local people to raise awareness of their significance. In spite of recognised potential threats, it is also clear that the species is relatively secure, at least for the next ten years and it is therefore difficult to justify conservation action for this species alone. However there is justification for conservation action for this species as part of wider conservation of wetland-dependent plants in the region.

One of the most important actions needed to enable protection of wetland-dependent sites, habitats and species in the region is to establish a sound scientific baseline toward designation of sites of conservation importance. The conservation status of more than 600 freshwater wetland-dependent plant species occurring in the Western Ghats has been assessed using the IUCN Red List Criteria. Over the last ten years Biju Punnakot has documented the vegetation of more than 600 seasonal ponds on the laterite toward submission of a PhD thesis in 2018, while Shijith Puthan Purayil has documented the vegetation of a number of laterite plateaus as part of a study of the conservation status of *Rotala malabarica*. This work has therefore already provided much of the information necessary to inform conservation of these sites and habitats. Most of the Red List assessments were completed in 2010 and there is a need for these to be repeated to include new data collected since the first assessments. Site and habitat-specific data need to be compiled into a document which provides explicit and detailed recommendations for formal recognition of priority areas for conservation of wetland-dependent plants in the region, to inform local and regional administrative organisations. This work should involve collaboration between Zoo Outreach Organisation, the IUCN SSC Western Ghats Plant Specialist Group, the IUCN SSC Freshwater Plant Specialist Group, Malabar Botanical Garden, the University of Calicut and the Government College Kasaragod supported by IUCN.

Figure 4.2 Students surveying and crossing a footbridge, while a woman washes clothes in the channel

Discovery of the five populations currently known has enabled development of a relatively precise characterisation of the ecology of *C. malabaricum*. Based on this, it is possible to define parameters which should enable a search of potentially suitable sites for this species which should then enable a more rigorous assessment of the conservation

status of the species. Searches should focus on rivers flowing over laterite between Kasaragod and Kannur, with at least part of their length flowing over relatively level ground at between 80-100 m altitude. This work should be carried out as soon as possible and any additional populations incorporated into the monitoring programme proposed here.

Action to protect specific sites in the short term, to ensure that they are not lost whilst the long-term conservation work is developed could include purchase of priority areas when they become available. This is particularly relevant to the site at Aravanchal which is threatened by conversions of adjacent laterite grassland to housing. This would effectively prevent any development of the habitats and ensure long-term protection. The aim of this purchase would be to establish a field research centre in the area on the purchased land, thereby maintaining a presence of conservation-oriented work in the area, promoting conservation of seasonal wetlands and the rivers by direct local action and potentially involving local people in conservation of these habitats.

4.2 Monitoring and further surveys

4.2.1 Context

The only means by which to measure population trends and therefore the true conservation status of each population is through replicable monitoring. To this end, a detailed monitoring protocol has been developed and is presented as Appendix A of this document. The aim of the monitoring protocol is to measure changes in the populations of *C. malabaricum* which can be interpreted as trends for the purpose of monitoring the condition of each population.

The extent to which *C. malabaricum* may depend upon sexual reproduction is not yet clear and cannot be dismissed, particularly as populations appear to be quite mobile. There is therefore a need to measure both the persistence of each population and the reproductive potential. Surveys in 2017 and 2022 have shown that even where the plant achieves 100% cover over the channel, the density of plants in a given river section can vary widely in response to factors such as changes in depth and substrate. Thus, although ideally there would be a benefit to collecting data on the precise size of the population (e.g. number of plants by size and age class) in practice this appears to be unreliable and is certainly too time-consuming to be practical. The monitoring protocol is therefore based on two complementary strands:

1. Measurement of sexual parameters to provide an indication of potential colonisation of new areas and recovery following loss.
2. Measurement of the extent to which vegetative cover persists between years, as an indication of survival of individual plants or re-colonisation of areas following loss.

Figure 4.3 Examples of reproductive characters: Left - unopened inflorescence; centre an inflorescence with one open flower and five buds; right an inflorescence with two open flowers and six buds

Figure 4.4 A mature fruiting head of *C. malabaricum* at Cheemeni in 2022, showing six ripe fruit, as well as two fruit which have been eaten by caterpillars

In addition, an attempt will be made to estimate population size, however recognising that this is inexact and should not be treated as too significant in assessment of conservation condition.

The aim is for survey data to be collected each year by staff of Zoo Outreach Organisation in collaboration with staff and students of the Government College Kasaragod. This will thereby not only enable acquisition of the desired quantitative data on reproductive potential but will provide an element of training in field survey techniques for botany students.

4.2.2 Vegetative cover

This element of the protocol is based on mapping the extent of each population. The main method by which to document both the extent of the population which is represented by different densities as well as the upstream and downstream limits of each population will be by use of a drone to fly over the length of river occupied by each population. Images obtained will be analysed both to establish the up- and downstream limits of the population and to derive a simplistic index of population density based on whether plants are at 80-100 % cover or less than 80 % cover. Where areas are inaccessible to the drone, gaps will be completed by eye.

At Periya, the drone record will be complemented by mapping as has been tested in 2017 and 2022. Two baseline maps have been prepared showing 500 m sections of the river for 1 km upstream of the road bridge (Appendix B). These will serve as a template for all mapping and the distribution of *C. malabaricum* will be marked onto the base maps, pacing lengths to improve the accuracy of mapping.

4.2.3 Sexual parameters

An estimate will be made of the reproductive potential of the population at Periya using methods employed in 2017 and 2022. Counts of reproductive structures will be made over the same 1 km length of river as will be marked onto the blank base maps, i.e., 1 km upstream of the road bridge. Reproductive characters will be recorded as follows:

Unopened inflorescence	=	Developing inflorescence, enclosed within the bracts at least to the extent that it is difficult to discern the number of floral parts within.
Buds	=	All unopened flowers from the stage when the bracts are sufficiently open to count the floral parts to (but not including) open flowers.
Flowers	=	Includes flowers from fully open to include bare ovaries which have yet to expand.
Unripe fruits	=	From the initial swelling of the ovaries to swollen but not reddish fruit.
Ripe fruit	=	Swollen, reddish to deep purple fruit. At this stage, any other floral parts which are not developed are excluded.

5 CONCLUSIONS

Conclusions based on all available data, combining field records from 2017 and 2022 with published information are as follows:

- *C. malabaricum* is endemic to reaches of five seasonal rivers flowing over level laterite at 80-100 m above sea level, in an area 20 x 5 km in Kannur and Kasaragod Districts, running parallel to the coast of northern Kerala. Populations appear to be limited upstream by reaches involving faster flow among bedrock outcrops and downstream by deeper water over silt.
- Population estimates based on detailed recording of the population at Periya suggest that the global population is in the region of 25,500 individuals distributed as follows: Aravanchal 500, Cheemeni 5,000, Embate 12,000 and Periya 8,000 individuals. All known populations have been abundantly fertile in both 2017 and 2022, flowering and setting seed abundantly from early September to late October. Potential seed-set in the population at Periya was estimated to be 2,250-33,750 in 2017 and 11,505-172,575 in 2022.
- Although *C. malabaricum* is capable of growing in full sunlight, this is rare, most populations occur in the shade either of natural riparian woodland and scrub or fruit crop plantations.
- *C. malabaricum* typically forms dense stands covering the entire channel with leaves which form a dense mat as water levels drop. Due to its size and growth form, it grows with few other plant species, although where instream habitats or human activities reduce the cover of *C. malabaricum*, a range of other species occur such as *Eriocaulon heterolepis*, *E. dalzellii*, *Lagenandra toxicaria* and *Cryptocoryne spiralis*. Where the canopy is more open, other species may occur, such as *Blyxa aubertii* var. *echinosperma*, *Limnophila repens* and *Limnophila aquatica*, with grasses such as *Isachne globosa*, *Oryza rufipogon* and *Sacciolepis interrupta* on the margins.
- All the rivers which support populations of *C. malabaricum* have been extensively modified by man, mostly with a 2-3 m high wall of laterite blocks along one or both margins, other significant modifications are mainly associated with road crossings. Where there are significant interventions, such as major crossings or sites where people regularly use the channel, this creates gaps in the stands of *C. malabaricum*.
- *C. malabaricum* is a major ecosystem architect, providing shelter for fish and invertebrate communities, dramatically modifying the hydrology of the rivers and almost certainly playing an important role in nutrient cycling.
- Overall, known populations of *C. malabaricum* may be considered stable and relatively secure, although there is potential for local actions to affect all populations. There is a suggestion that populations are in unfavourable condition at Cheemeni due to the rubber plantation, threatened at Aravanchal by housing and possibly declining at Embate due to development. There is clearly need for monitoring at all these sites to establish population trends.
- The Red List Assessment for *C. malabaricum* needs to be revised, probably to Vulnerable D2, based on the small number of populations.
- The apparent absence of a mechanism for formal protection of sites supporting *C. malabaricum* highlights the need for surveys of potentially suitable habitat within the known range of the species, as well as for monitoring of all know populations to identify population trends.
- There is a need for a major initiative to stimulate and support conservation of wetland plants throughout the Western Ghats, to ensure conservation of the species and other taxa endemic to the region.

REFERENCES

IUCN. 2016. The IUCN Red List of Threatened Species. Version 2016-1. Available at: www.iucnredlist.org. (Accessed: 30 June 2016).

Lansdown, R.V. 2007 The identity of *Ranunculus* subgenus Batrachium in the River Itchen. Environment Agency, Southern Region.

Lansdown, R.V. 2016. *Crinum malabaricum*. The IUCN Red List of Threatened Species 2016: e.T69726391A69727184. https://dx.doi.org/10.2305/IUCN.UK.2016-1.RLTS.T69726391A69727184.en. Accessed on 06 October 2022.

Lansdown, R.V. and Molur, S. 2017 Development of a conservation plan for Malabar river-lily (*Crinum malabaricum*). IUCN SSC Freshwater Plant Specialist Group. Unpublished report to Mohamed Bin Zayed Species Conservation Fund, Abu Dhabi.

Lekhak, M.M. and Yadav, S.R. 2012. *Crinum malabaricum* (Amaryllidaceae), a remarkable new aquatic species from Kerala, India and lectotypification of *Crinum thaianum*. *Kew Bulletin* 67(521-526).

Pradissan, R. and Pipatcharoenchai, W. 2008 Biology of onion plant, Crinum thaianum Schulze: Technical paper no. 65/2008. Aquatic Plant and Ornamental Fish Research Institute, Department of Fisheries, Bangkok, Thailand.

APPENDIX A A PROPOSED MONITORING PROTOCOL

The combined surveys carried out with the help of lecturers and students from the Government College Kasaragod in 2017 and 2022 can serve as a baseline for monitoring *C. malabaricum*. Data will be collected annually by Zoo Outreach and the Government College Kasaragod, from two abutted 500 m section running upstream from the road.

Data collection is based on two approaches:

- The extent and distribution of stands of *C. malabaricum* will be mapped onto the base maps presented as Figures A1-A2. Using the following codes


Crinum malabaricum


Emergent or marginal monocots


Emergent dicots

Direction of flow

- Details of flowering and seed production are recorded to enable an estimate of potential reproductive output for the year as follows:

Unopened inflorescence	=	Developing inflorescence, enclosed within the bracts at least to the extent that it is difficult to discern the number of floral parts within.
Buds	=	All unopened flowers from the stage when the bracts are sufficiently open to count the floral parts to (but not including) open flowers.
Flowers	=	Includes flowers from fully open to include bare ovaries which have yet to expand.
Unripe fruits	=	From the initial swelling of the ovaries to swollen but not reddish fruit.
Ripe fruit	=	Swollen, reddish to deep purple fruit. At this stage, any other floral parts which are not developed are not excluded.

Counts of plants are as precise as possible and may involve counts of individuals where plants are relatively sparse, but where the population is very dense, a count is made of a sub-set which is then extrapolated up to represent a larger area.

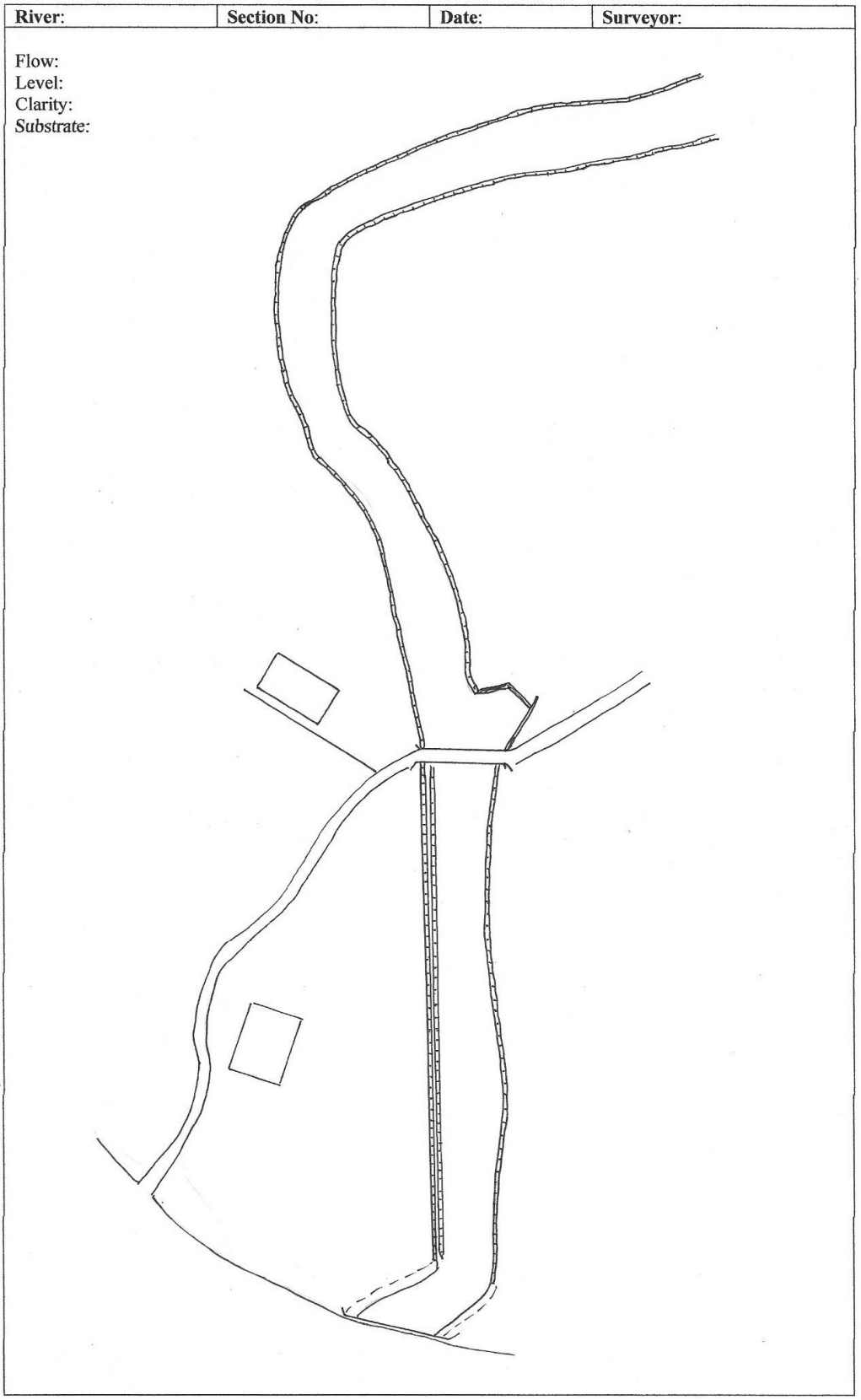

Figure A1 The first 500 m section upstream of the road bridge at Periya

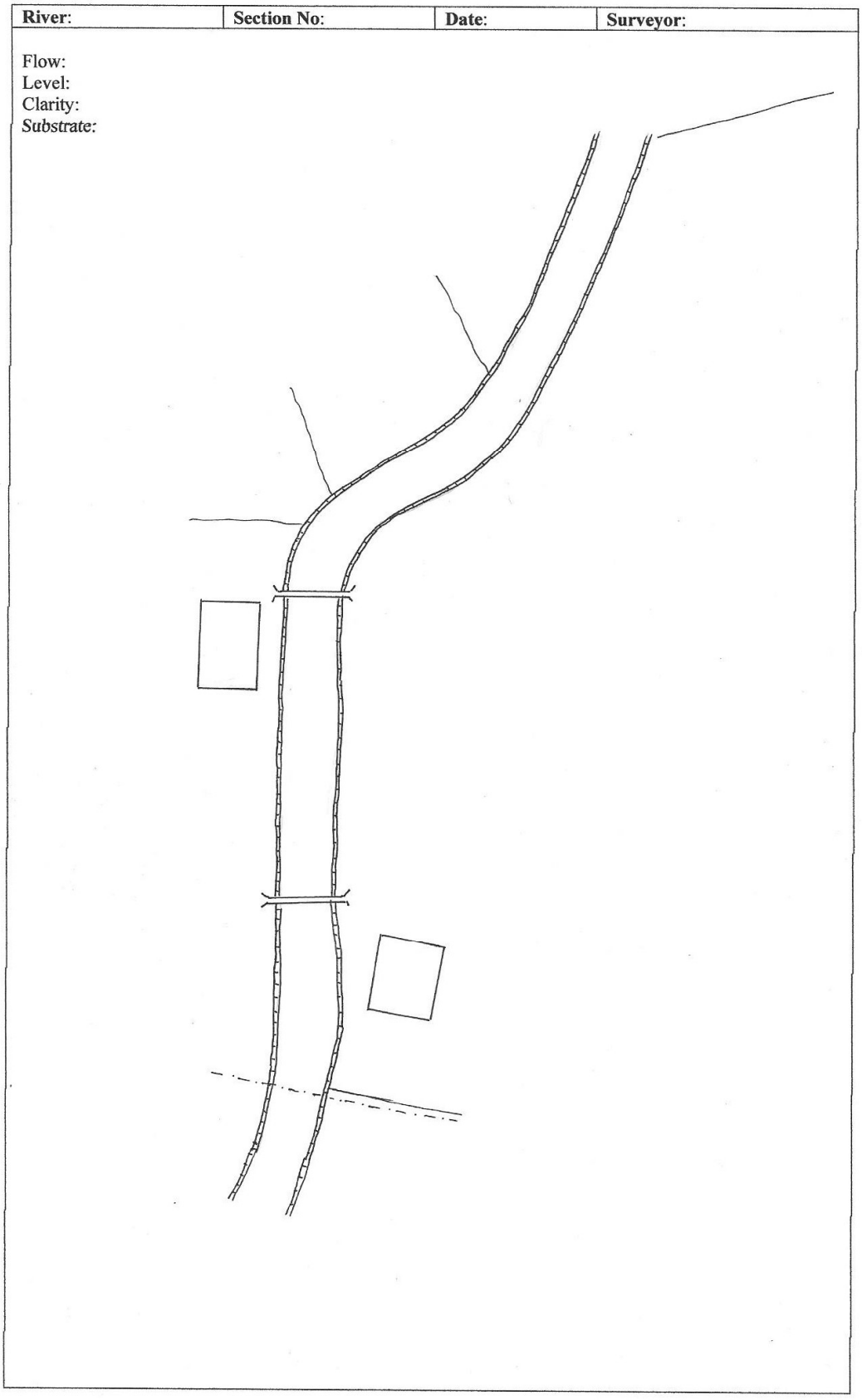

Figure A2 The second 500 m section upstream of the road bridge at Periya (immediately upstream of section A1)